Available online at www.sciencedirect.com
ScienceDirect
Procedia - Social and Behavioral Sciences 103 (2013) 991 – 998
Procedia
Social and Behavioral Sciences

13th International Educational Technology Conference

The development and evaluation of a Kinect sensor assisted learning system on the spatial visualization skills

Chih-Hsiao Tsai[a*], Jung-Chuan Yen[b]

[*a]*Department of Information Technology,*
[b]*Department of Mathematics and Information Education,*
[*, a]*Takming University of Science and Technology, 56, Sec.1, Huan-Shan Rd., Nei-Hu District, Taipei, 11451, Taiwan*
[b]*National Taipei University of Education, 134, Sec. 2, Heping E. Rd., Da-An District, Taipei, 10671, Taiwan*

Abstract

In this study, we proposed a cubic net assisted learning system by using Kinect sensor technologies for enhancing learners' spatial ability. The content of the system is based on the geometric learning theory, and 3D real-time objects used to provide the different viewing angle control. The goal of the proposed system is to facilitating learners' motivation by providing realistic 3D-visual materials and to evaluate the effects of specific operating experiences. As the advantages of Kinect SDK (Software Development Kit), our system employs body and depth tracking function to help learners using their hand to operate objects. The result of the System Usability Scale (SUS) showed that our system is usability and learnability. According to the evaluation results, we concluded that Kinect sensor assisted learning system not only could promote in developing the students' spatial visualization skills, but also encourage them to become the active learner.

Selection and peer-review under responsibility of The Association of Science, Education and Technology-TASET, Sakarya Universitesi, Turkey.

Keywords: Kinect sensor; augmented reality; spatial ability; geometric learning theory; system usability scale

[*] Corresponding author. Tel.: +886-9-1254-1115; fax: +886-2-2799-1368.
E-mail address: chtsai2104@gmail.com.

Selection and peer-review under responsibility of The Association of Science, Education and Technology-TASET, Sakarya Universitesi, Turkey.
doi:10.1016/j.sbspro.2013.10.423

1. Introduction

Learning with virtual objects integrated into reality interactive technologies has led to new digital learning type (Lin, Chen, Hsieh, Lee, & Huang, 2012) in recent years, and has become the heated discussion issue of e-learning research. However, in order to guide learners to learn scientific knowledge quickly and efficiently, the integration of innovative technologies into scientific learning activities without distracts their focus of learning should be an important research topic.

With the increasing usage of physically interactive and augmented reality, game-based learning requirements for digital learning application have become more critical. Learners are able to learn better since they use multimedia assisted learning system, which would make them more motivated to pay attention to the information presented and better retain the information. Lu & Yao (2002) also stated that presenting abstract material using multimedia enables learners to understand the material better, and audio and visual displays allow learners to interact with the material. Although teachers' professional education seemed to play an important role in the teaching process, but we still need an innovation instructional designs which differ from traditional teaching. We have to change education mode from "Technology-adapted Instruction" to "Instruction-adapted Technology" (Sung, Chang, & Hou, 2005). It is difficult for most learners to reasoning and conversion of Shape and Space in the field of elementary school mathematics education, so it causes lower learning achievement than the other units (Wang & Wang, 2008). However, spatial ability plays a very important role in the learning of mathematics geometry (Wheately, 1990; Wu, 2004; Wei, 2005).

The NCTM (2000) consider that the geometry help students to analyze characteristics of geometric shapes, as well as to use visualization, spatial reasoning, and geometric modeling to solve problems. Van Hiele (1986) describes a theory of mathematics education, the development of geometric thought, to enhance the achievement of learning and to promote learners' comprehension. Van Hiele suggested five teaching phases to design teaching methods and materials step-by-step. This model of teaching phases is used as the main theoretical framework for this study. Game-based learning (GBL) is an instructional method that incorporates educational content or learning principles into video games with the goal of engaging learners. The use of this method in the field of natural science and technology has increasingly been the object of study in recent years. Learning through digital games not only increase motivation, active learning, and provide individual learning opportunities, but reduce the learning pressure of learners (Wu, 2007).

The main issues of this study focus on developing and evaluating a cubic net interactive system by using Kinect sensor for enhancing learners' spatial ability. We will develop a courseware for interactive learning on cubic net in elementary school refers to a lesson of "Mathematics Space Geometry". The content of the system is based on the geometric learning theory, and 3D real-time objects are used to provide the different viewing angle control. A qualitative analysis is also performed to show learners' interactive of the Kinect sensor design through observation record, video recording, and structural interviews. And the questionnaire of system usability scale is utilized to evaluate system usability.

For these objectives to be achieved, the article is structured as follows. The first section deals with the foundations for the development of the research. After which research methodology is presented, with full details of the system development, and of the instrument and procedures used. Results and then presented, with a thorough description of the system usability. Finally results are discussed and conclusions are drawn.

2. Literature Review

2.1. Spatial visualization skill

Bishop (1989) refers to the power of spatial ability to help learner in visual and figural representation and to introduce complex abstractions in mathematics. Piaget & Inhelder (1967) think that the child first recognizes various objects by sense of touch alone and is followed by building up and using certain primitive relationships (topological space). Contrary to the historical development of geometry which began with treatment of straight lines, angles, distances, and plane figures, the child begins by noting the topological as opposed to the metric properties of objects (projective space and Euclidean space). Lohman & Kyllonen (1984) and Linn & Petersen (1985) think that spatial ability includes spatial visualization, spatial perception, spatial orientation, spatial imagination, and spatial translation and transformation. In this study, we focus on the spatial visualization skill which is the ability to mentally manipulate complex spatial 2-dimensional and 3-dimensional figures. Van Hiele (1986) describes a theory of mathematics education, Development of Geometric Thought, to enhance the achievement of learning and to promote learners' comprehension. Van Hiele suggested five teaching phases to design teaching methods and materials step-by-step (see Table 1).

Table 1. The model of the Development of Geometric Thought

Level	Phases of learning
Level0 Visualization	Inquiry/information
Level1 Analysis	Directed oriented
Level2 Informal deduction	Explication
Level3 Formal deduction	Directed oriented
Level4 Rigor	Integration

2.2. Kinect for Windows

Kinect for Windows gives computers eyes, ears, and the capacity to use them (Kinect for Windows, 2013). Its OpenNI framework and SDK architecture show in Fig. 1. Kinect sensor gets the information stream (such as video, depth, and audio stream) and delivers to Natural User Interface (NUI) library. We operate through application interface (API) to control all functions of Kinect sensor, such as hand tracking, skeleton tracking (Kar, 2010), speech commands, and face tracking.

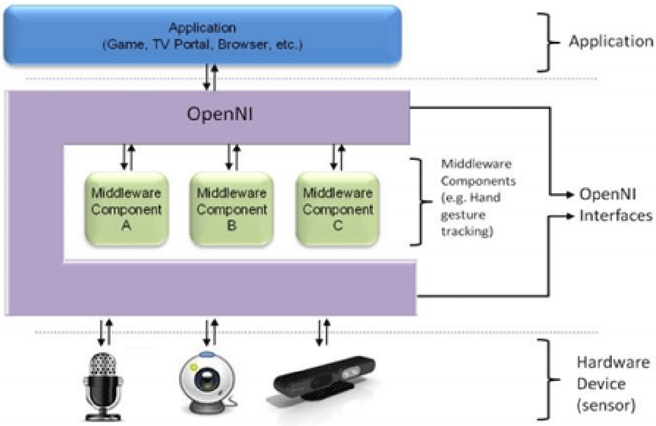

Fig. 1. Kinect for Windows OpenNI framework. (Data source: http://yannickloriot.com/)

2.3. Game-based learning

Game based learning (GBL) is a specific term of instructional strategy or activities that deals with applications that have defined learning outcomes. As an emergent learning process, game-based learning is designed to balance the subject matter with the gameplay and to help the player to retain and apply the subject matter to the real world (Kiili, 2005; Prensky, 2001). Game-based learning usually uses video-game technology, scoring strategy, interactive interface, flexibility course, and real-time feedback to engage learners into their learning (Drummond, 2003). It not only makes learning more meaningful but also creates a mental model which is response to participants' motivation (Chumbley & Griffiths, 2006; Provenzo, 1992).

With the rapidly development of information and communication technology, computer and simulation games have become the most popular leisure activities in our daily life. Many educational scholars claim that computer game is the natural and necessary element of student's learning and it should be integrated into the instructional design as well as learning environments (Kiili, 2005; Prensky, 2001). They also believe that playing computer games applies the concept to "learning by playing", which helps students overcome the boredom of learning in the classroom (Nanjappa, 2001; De Freitas, 2006). However, there are still some weaknesses and drawbacks in the implementation of game-based learning: (a) Game-based learning needs a lot of preparations and efforts; (b) the subjects and contents usually are pre-defined and fixed. More specifically, the workload of these tasks is very large and the completion of the application may not really meet the demand (Charles, Charles, & McNeill, 2009). On the other hand, e-learning systems are usually designed to support alternative methods for traditional instruction in order to improve the quality of student learning and to reduce the costs of instruction (Twigg, 2003). Hence, the game-based e-learning has been proposed. As Clark and Mayer (2003) noted in their review of e-learning, well-designed system can help generate the contents of entertaining scenario that correspond to the learning subject. Stated another way, game-based e-learning system should make the preparations of learning applications with less efforts and better efficiency.

3. System Development

3.1. Teaching materials

To develop material employing Kinect sensor, different programming frameworks must be surveyed, the OpenNI architecture to control Kinect sensor and OpenTK to provide cross-platform library (Fig. 2). By employing Kinect senor to present the questions and interactive games, and including a hand-mouse function, learners can learn the geometric learning theory and related information (Fig. 3 shows the system process.).

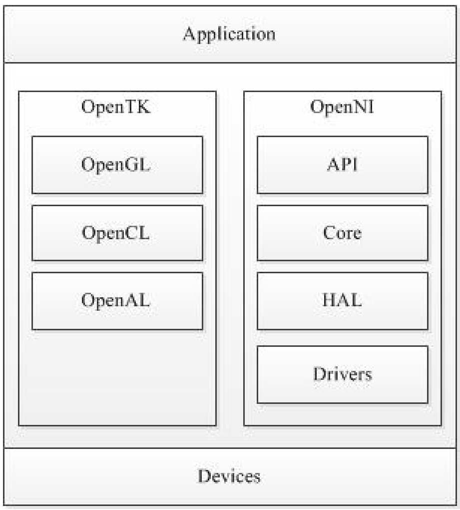

Fig. 2. System stack overview

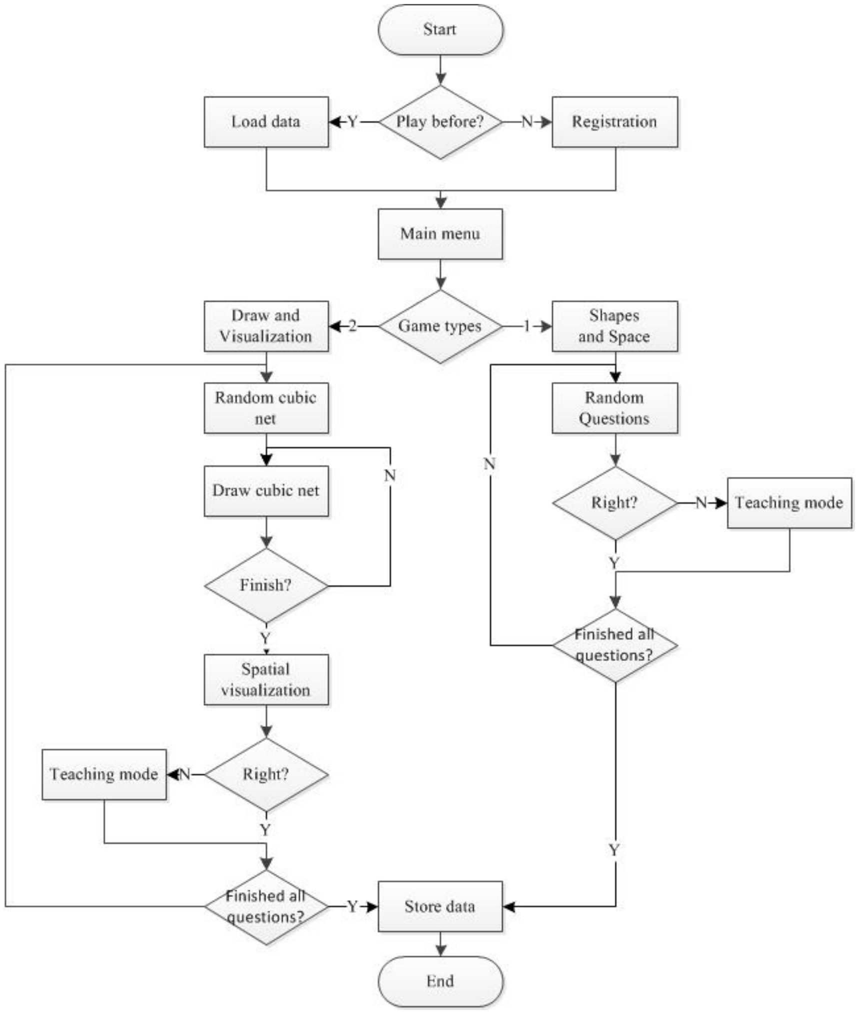

Fig. 3. Kinect sensor assisted learning system process.

3.2. Experimental subjects and operation

Subjects are 98 students from the University of Technology in north Taiwan and they take information technology and science courses. We utilize System Usability Scale (SUS) (Brooke, 1986) which is a questionnaire of Likert Scale to assess system usability, learnability and users' subjective satisfaction with specific aspects of the interactive interface. In addition, we add an adjective scale to rating our SUS scale (Fig. 5), this SUS was highly reliable (alpha = 0.91) and useful over a wide range of interface types (Bangor, Kortum, & Miller, 2009). While SUS was only intended to measure perceived ease-of-use, Lewis, & Sauro (2009) show that it provides a global measure of system satisfaction and sub-scales of usability (items 1, 2, 3, 5, 6, 7, 8, 9) and learnability (items 4 and 10) (multiplied their summed score contributions by 3.125 and 12.5, respectively).

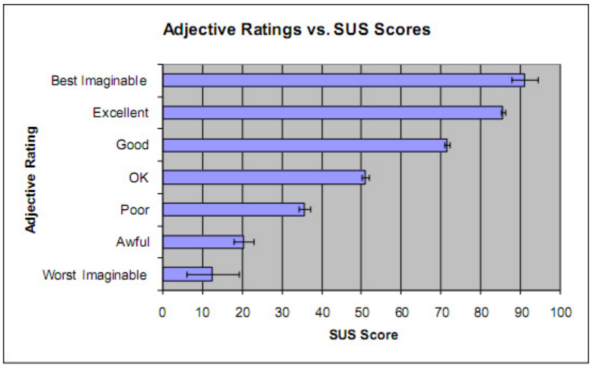

Fig. 4. Mean SUS score ratings corresponding to the seven adjective ratings.
(Data source: Bangor, Kortum, & Miller, 2009)

The teaching materials employing Kinect sensor developed in this study required the use of computers. The learners were stand in front of Kinect sensor and provided information regarding the course (see Fig. 6).

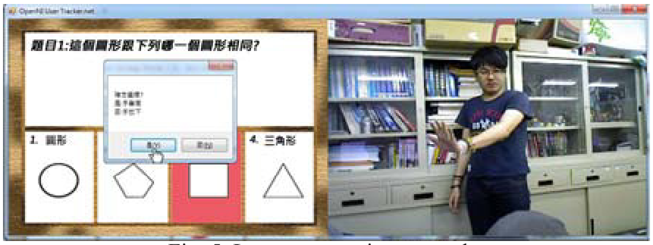

Fig. 5. Learner operation example.

4. Evaluation Results

Subjects finish operating the system and fill out the SUS questionnaire. As summarized in Table 2, the mean score of SUS is 71.73 (SD=13.06). According to the adjective ratings score, the assisted learning system in this study closely matches subjective label between Good and Excellent. We have discussion with these subjects on their idea about the interactive learning system after they complete operating the system and filling out the SUS questionnaire. Subjects generally agreed that interactive learning system increase their interest in the concept and make them to find different things.

For the analysis of the questionnaire, will further discuss the mean score, usability score, and learnability score and help us to improve system. Hence, we summarized the following reasons may affect the system satisfaction.

- The control and learning interface are not smooth enough.
- The materials cannot display properly due to the angle and distance, this situation may confuse learners' operation.
- Learners need the support of technical assistant. Some learners do not understand how to operate the system. So we will provide teaching documents or assistant to help them.

Table 2. SUS scoring

Mean	SD	Min	Max	Median	Usability	Learnability
71.13	13.06	45	100	70	71.08	74.36

5. Conclusion and Future Work

In this paper, we present the results of the usability and the learnability of cubic net assisted learning system by using Kinect sensor. Regarding the SUS questionnaire, most learners highly appreciated the teaching materials employing Kinect sensor and considered the materials interesting, easier to control and play, and easy to operate using the interactive functions. The learners also reported that the teaching employing interactive system enhanced their motivation to learn and was helpful for learning spatial skills. In the future, there are still many parts of system to improve. A small portion of the learners reported that the teaching material employing Kinect sensor performed less desirable response speed during interactive operation. The buttons should be clearly defined, the cubit net knowledge should be highlighted, and proper instructions should be provided to ensure the learners are more focused on learning the knowledge expressed in the teaching materials.

Acknowledgements

The funding of this study was supported by the National Science Council of Taiwan under grant NSC 101-2511-S-147 -001 -.

References

Bishop, A. J. (1989). Review of research on visualization in mathematics education. *Focus on Learning Problems in Mathematics*, 11(1), 7-16.

Bongor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of Usability Studies*, 4(3), 114-123.

Boytchev, P., Chehlarova, T. & Sendova, E. (2007). *Virtual Reality vs Real Virtuality in Mathematics Teaching and Learning*. Primary Education Informatics, Mathematics, and ICT: a 'golden triangle', Boston.

Brooke, J. (1986). *System usability scale (SUS): a quick-and-dirty method of system evaluation user information*. Reading, UK: Digital Equipment Co Ltd.

Charles, D. K., Charles, T., & McNeill, M. D. J. (2009). Using player and world representation techniques from computer games to improve student engagement. The First IEEE International Conference in Games and Virtual Worlds, Coventry, March 23-24, 2009

Chumbley, J. & Griffiths, M. (2006). Affect and the computer game player: The effect of gender, personality, and game reinforcement structure on affective responses to computer game play. *Cyber Psychology and Behavior, 9*(3), 308-316.

Clark, R. C. & Mayer, R. E. (2003). *E-learning and the science of instruction*. San Francisco: Pfeiffer.

De Freitas, S. (2006). Using games and simulations for supporting learning (Eds). C. Martin and L. Murray. *Learning, Media and Technology*. Special Issue on Gaming.

Dennis, J. R., & Kansky, R. J. (1984). Electronic slices of reality: The instructional role of computerized simulations. In J. R. Dennis & R. J. Kansky (Eds.), *Instructional computing: an acting guide for educators*. Glenview, Illinois: Scott, Foresman.

Drummond, C. N. (2003). Game-based learning. *Journal of Geoscience Education, 51*(4), 357.

Dubois E., & Nigay,L. (2000). Augmented Reality : Which Augmentation for Which Reality? *Proceedings of DARE 2000 on Designing augmented reality environments*, 165-166.

Harada, K., Gallou-Dumiel, E., & Nohda, N. (2000). The role of figures in geometrical, proof-problem solving – students' cognitions of geometrical figures in France and Japan. *Proceedings of the Twenty-fourth PME Conference*, 3, 25-32.

Lewis, J. R., & Sauro, J. (2009) The factor structure Of The System Usability Scale. *Proceedings of the Human Computer Interaction International Conference* (HCII 2009), San Diego, CA, USA

Kar, A. (2010). Skeletal Tracking using Microsoft Kinect. *Methodology*, 1, 1–11.

Kaufmann, H., & Schmalstieg, D. (2003). Mathematics and geometry education with collaborative augmented reality. *Computers & Graphics*, 27, 339-345.

Kaufmann, H. (2006). The Potential of Augmented Reality in Dynamic Geometry Education. *Proceedings of the 12th International Conference on Geometry and Graphics (ICGG) 2006*.
Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *The Internet and Higher Education*, 8(1): 13-24.
Kinect for Windows (2013). Retrieved April 20, 2013 from http://www.microsoft.com/en-us/kinectforwindows/
Linn, M.C., & Petersen, A. C. (1985). Emergence and characterization of sex in spatial ability:A meta-analysis. *Child Development*, 56, 1479-1498.
Lin, S. C., Chen, K. H., Hsieh, W. C., Lee, W. T., & Huang, K. C. (2012). Somatosensory interaction in digital game-based learning for Taiwanese classical poems. *Proceedings of Global Chinese Conference Computers in Education*. pp.187-194.
Lohman, D. F., & Kyllonen, P. C. (1984). *Individual differences in solution strategy on spatial and change*. In S. Koch (Ed.), Psychology: A Study of Science, (3), pp. 423-475, New York: McGraw Hill.
Lu, C. C., & Yao, N. D. (2002). The Application and Introspection of Information Education in Elementary-school Curriculum, *Elementary Education*, 42(6), 19-24
Mayer, R. E. (2003). The promise of multimedia learning: using the same instructional. *Campus-Wide information system*, 13, 125-139.
Nanjappa, A. (2001). *Educational games: Learners as creators*. The University of Memphis.
National Council of Teachers of Mathematics (2007). *Exploring the Isometric Drawing Tool*. Retrieved April 20, 2013 from http://illuminations.nctm.org/
National Council of Teachers of Mathematics (2000). *Principles and standards for School mathematics.* Reston, VA: Author.
Pai, Y. X. (2005). The study on using augmented reality for multi-players interactive situation-example by game learning. *Master thesis*, Yuan Ze University, Taiwan, ROC.
Piaget, J., & Inhelder, B. (1967). *The child's conception of space*. New York, NY: Norton.
Prensky, M. (2001). *Digital game-based learning*. NY: McGraw-Hill.
Provenzo, E. (1992). The video generation. *American School Board. 179*(3), 29-32.
Resnick, M., and Ocko, S. (1991). LEGO/Logo: learning through and about design. *In Constructionism* (pp. 141-150), NJ: Ablex Publishing.
Rusk, N., Resnick, M., Berg, R., & Pezalla-Granlund, M. (2008). New pathways into robotics: strategies for broadening participation. *Journal of Science Education and Technology*, 17(1), 59-69.
Su, C. C. (2004). Using AR for children to promote Chinese phonetic alphabet learning. *Master thesis*, National Cheng Kung University, Taiwan, R.O.C.
Sung, Y. T., Chang, K. E., & Hou, H. T. (2005). Technology-instruction integration: learning form America's experience and reflecting on Taiwan's development. *Bulletin of Educational Research*, 51(1), 31-62
Tsao, T. S. (2012). Kinect for Windows development-learning by doing. Retrieved April 20, 2013, from http://msdn.microsoft.com/zh-tw/hh367958.aspx
Twigg, A. C. (2003). Improving learning and reducing costs: new models for online learning. *Educause Review, 38*(5), 28-38.
Van Hiele, P. M. (1986). *Structure and insight: a theory of mathematics education*. Orlando, FL: Academic Press.
Wang, H. W., & Wang, Y. Y. (2008). A study of developing a game-based courseware for cubic net. *Elementary Education*, 49(1), 30-40.
Wei, C. L. (2005). The Study of Information Technology Integrated into the Teaching of Solid Net for Fourth Graders, *Master thesis*, National Cheng Kung University, Taiwan, R.O.C.
Wheatley, G. H. (1990). Spatial sense and mathematics learning. *Arithmetic Teacher*, 37(6), 10-11.
Wu, M. Y. The study of spatial ability learning for fourth graders: take solid geometric net as an example. *Master thesis*, National Taipei University of Education, Taiwan, ROC.
Wu, T. K. (2007). Development of a gamed-based learning system for enhancing learner's motivation and self-perception in energy education. *Master thesis*, National Central University, Taiwan, ROC.